Affective Computing
Prof. Jainendra Shukla
Department of Computer Science and Engineering
Indraprastha Institute of Information Technology, Delhi

Week - 07
Lecture - 02
Skin Conductance and Emotion

Hi friends. So, in the last lecture we discussed about the emotions in the heart rate. And following the same we will today discuss the emotions in another very interesting physiological signal that is the Skin Conductance.

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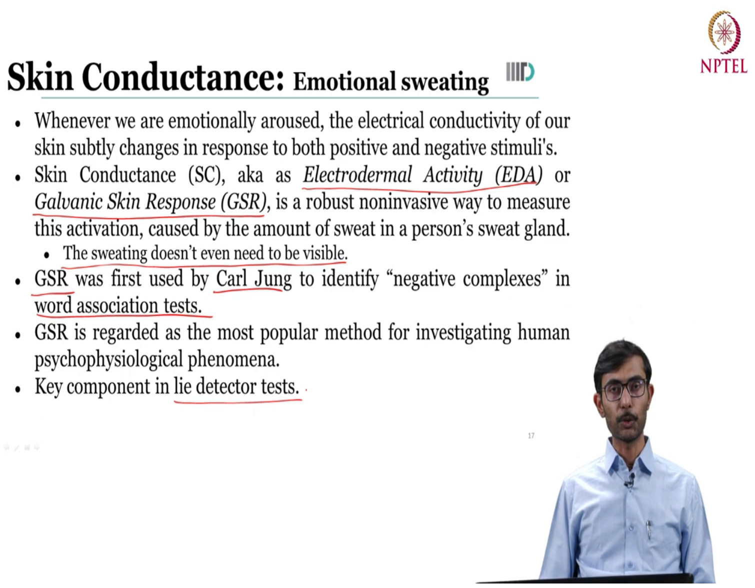

So, skin conductance is also refers to as the emotional sweating for the reasons that we will discuss now. So, whenever we are emotionally aroused you may have observed also that the electrical conductivity of a skin it subtly changes and in response to the positive as well as the negative stimuli's.

And one example that you may have seen is trying to recall a fact in front of an audience when you are giving some very important presentation, right. So, when you are not able to recall that you are feeling very aroused, very stressed, very anxious and then suddenly you may have seen you are sweating, suddenly you are sweating, right.

But nevertheless, even if the amount of sweating is not so much or is not so high then also we can observe the subtle changes in the electrical conductivity of the skin and that is what is known as the skin conductance or alternatively it is also referred to as the Electrodermal Activity or Galvanic Skin Response. So, this GSR, EDA or the SC is a robust non-invasive way to measure this kind of activation and which is definitely caused by the amount of the sweat in a person's sweat gland for the reasons that we just discuss.

It could be because of the positive or the negative stimuli which is making you anxious, which is making you aroused, right. And as I said before most important thing is that you need not to have a kind of sweating which is very very visible, right. It is not like you will be getting wet entirely, right. So, it can be very very subtle, it may not be very visible on the skin, but it causes subtle changes in the electrical conductivity which can be captured by the GSR sensors.

So, GSR was first used I believe 1980s or 70s by a researcher named Carl Jung in to identify the negative complexes in the word association test. So, some of you may know about the word association test. So, basically the word association test is a very popular psychological test in which what happens that you are shown a series of words, a positive or the negative words for a duration of 15 seconds on a screen and you are asked to respond with the very first word that comes spontaneously in your mind or in your thoughts, right.

So, for example, maybe I asked you a word I as baby. So, maybe the first word that comes out the cute and then so on and so forth. You got the idea, right. So, for example, I would say about knife. So, the very first word that maybe comes to your mind may be kitchen, I do not know. Different individuals may come up with the different sort of words and that is what is known as the word association test.

So, basically Carl Jung what he showed with the help of the galvanic skin response signals that when the individuals were coming up with the negative words, right, in response to the this word association tests, in response to this word association and that was sort of getting captured or getting highlighted by the galvanic skin response of those individuals or of those instances.

So, this was the very first sighting of the galvanic skin response and its use. And since henceforth you know the GSR has been regarded as one of the most popular method for investigating human's psychophysiological phenomena, right. And you may be knowing also that GSR is a key component in so called or very very popular lie detector test.

So, you may have seen in the movies or in the series that many times the law enforcement agencies they use this lie detector test and one of the primary components of those lie detector tests are these galvanic skin response sensors. Nevertheless, we will not be talking about that, but for the interested audience I would definitely request you to please go ahead and investigate more about it.

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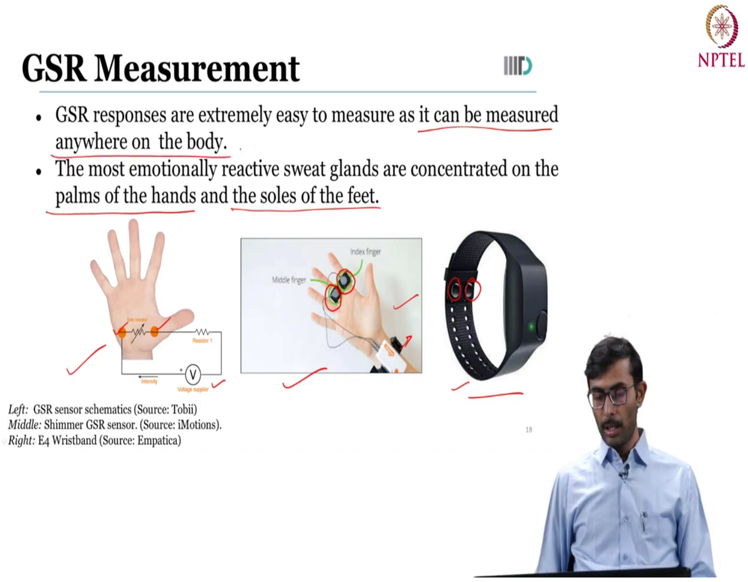

Now, let us try to discuss and understand how can we measure the GSR signals. So, it turns out that the measurement for the GSR signals is quite easy as it can be measured anywhere on the body. And the reason it can be measured anywhere on the body because we try to capture the electrical a conductance or the electrical activity of the skin and of course, the skin constitutes the largest organ of our body.

So, it is all over our body, right. But of course, nevertheless there are certain areas of the of our body which are emotionally more which have emotionally more reactive sweat glands. And for the same reason we try to concentrate on those areas when we are capturing the galvanic skin response signals.

And these areas are primarily the palms of the hands and the soles of the feet. So, basically the soles of the feet and of course, the palm of the hands as you can see in the this diagram the schematic diagram that you can get this use this palms of the hands and then you may have observed that while sweating also these are the areas where usually you sweat a lot, right.

So, for example, this particular graph that you are looking at in the screen it shows you a schematic of the GSR sensor. So, it is a very very easy schematics. So, here basically what you have, you have a simply through a voltage supplier a constant very small amount of voltage is passed through the GSR electrodes. So, basically these are the two electrodes that you can see.

And then the difference across these GSR electrodes in terms of the voltage is measured and that is what is constituted as the GSR a signal of the human body. Now, there are different types of sensors that are available in the market. So, for example, if you look at this particular diagram then this is the Shimmer GSR plus sensor and you can see that it also has the same based on this is schematics it also has two sensors.

So, for example, this is one cell sorry, electrode this is another electrode and of course, then there is a this device which sort of is responsible for producing this constant supply of the voltage and at the same time it has this Bluetooth chip inside it which transfers the signal wirelessly from the participant or from the human's hand to the whatever device where you are capturing the data.

So, that is for example, one popular device. Another for example, sort of popular device is the E4 wristband. So, this is the E4 wristband by the Empatica industry Empatica start-ups. So, basically you can see again here you can the these two electrodes are very well visible you can see and more or less the idea is the same. So, basically you know you wear it as a wrist watch. So, basically these two electrodes they get attached here and then from here also you try to get the GSR signal.

So, as you can see so, for example, in this you can you are getting this from the fingers, in this you are getting it below beneath the palm and so on and of course, there are other sensors which are available from which you can attach the sensors at the soles of the feet and you can get the GSR signal from there. So, as I said as we said before that it is quite easy to measure as it can be measured anywhere on the body, right.

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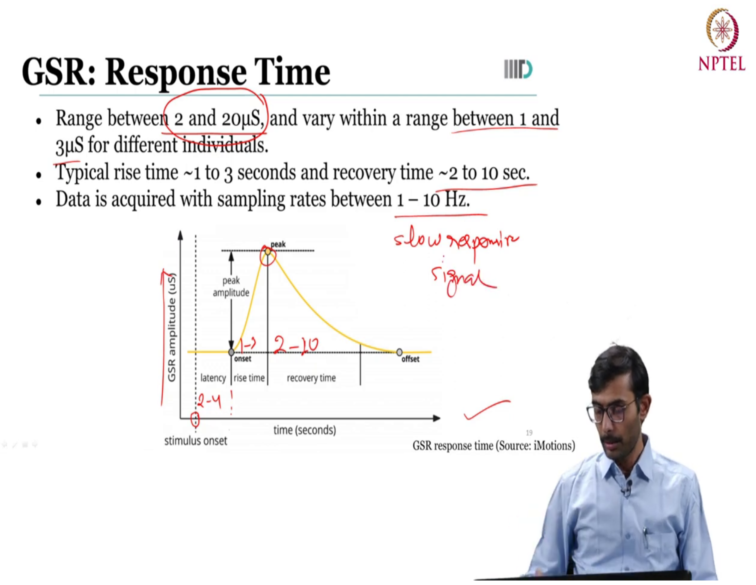

So, then now you have let us look at that what is the nature what does the nature of the GSR signal look like. So, for example, you can see a very nice GSR response time diagram on the below. So, basically what it turns out that always from the onset of the stimulus there is a latency, there is a delay with which the response in the GSR signal occurs, right. And usually this delay for example, this latency can be 2 to 4 seconds. So, what it means? That it may take up to 2 seconds for the GSR signal to start reflecting the response from the onset of the stimuli.

So, imagine that you were presented with an image of in an image or a video or any stimuli for that matter and then it may take up to let us say 2 seconds, 3 seconds or even 4 seconds for the GSR signal response to occur in response to the video or the image that you just saw or you are just seeing, right. So, that is what is the typical delay. Now, of course, the range for this the amplitude of this GSR signal basically this part it is it varies between 2 to 20 microsiemens.

So, basically microsiemens is the opposite of the voltage, you can kept you can convert it into the voltage as well and for the individual individuals it may vary between the 1 to 3 seconds. So, basically you know 2 to 20 microsiemens is the typical range and then it may vary 1 to 3 microseconds more, Siemens more so for the different individuals depending upon the individual variability. So, this is the typical range of the GSR signal.

Now, if you look at the GSR signal rise response time here response here then you will notice that there is a particular rise time which the signal takes to reach to its peak value and then there is a recovery time which is the time that the signal takes from its peak to coming to an offset or coming to the let us say within 10 percent of the within 10 percent of the GSR's amplitude.

So, the typical rise time is always higher than the recovery time. So, basically it takes 1 to 3 seconds here it takes sorry, 1 to 3 seconds for the rising of the GSR signal; that is it takes around 1 to 3 seconds for the GSR signal to rise from the baseline to the to its peak value. And then it takes another 2 to 10 seconds anywhere between 2 to 10 seconds to go down to the baseline value from the from its peak value, right. So, that is how it typically responds.

And it turns out that the GSR signal is usually sampled at a very very low frequency such as between 1 to 10 hertz. Say, usually 10 hertz is pretty common to have. So, we do not sample it at a higher frequency because it is not as responsive and it is not a very very fast signal it turns out, right. So, that is what the response time of the GSR signal looks like and usually it is all known as the very slow responsive signal. So, it is a very slow responsive signal, right, perfect.

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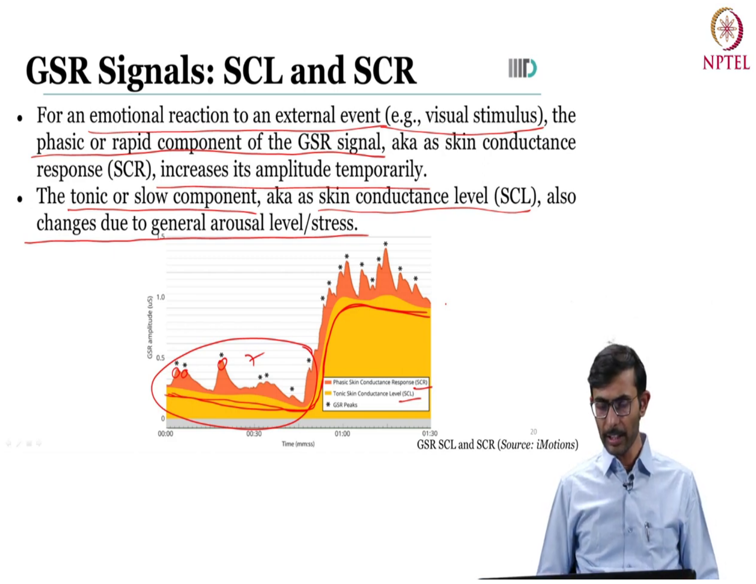

So, having understood the GSR's signals response time let us try to look at that what are the different types of components in the GSR signal. So, the GSR signal typically it is it consists of two components. One is known as the Skin Conductance Response SCR and another is known as the known as the Skin Conductance Level. So, basically the skin conductance response is the phasic or rapid component of the GSR signal.

What it means that in response to an in response to an external event which could be any stimulus the skin conductance sorry, the skin conductance signal or the GSR signal has a phasic or rapid component which increases in the in its amplitude temporarily. So, for example, if you can see this is the typical these are the GSR peaks and this is the overall GSR signal.

But if you look at these signals for example, these are the amplitudes which are raising much temporarily and much frequently also. So, for example, if you look at the overall shape of the GSR signal then in comparison to this overall shape of the GSR signal there are temporarily and sudden rises in the amplitude of the GSR signal which is known as the phasic skin conductance response.

And usually, this phasic skin conductance response it is an reaction to an external event. It of course, it may occur in the sense of the emotional external event as well, but what we are interested in, we are interested in when it is occurring in response to some event. And many times, when we are doing the analysis of the GSR signal we are more interested in the analysis of the SCR signals.

In and it turns out of course, the way we have the phasic or the rapid component of the GSR signal, in the same way we have a tonic or is also known as the slow component of the GSR signal which is known as the Skin Conductance Level or SCL. So, basically the skin conductance level or the SCL component of the GSR signal it changes due to the general arousal level or general stress, right.

So, basically as you can see the change. So, for example, while analyzing the SCL these this is what the SCL looks like as I said before, this is what is the SCL component looks like. So, if you look at the entire pattern of the SCL signal the changes are not many right, I mean.

So, in the same period for example, in the same period maybe you saw that 1, 2, 3, 4, 5, 6 maybe there were like the amplitude of the SCR component increased 7 times, but then in the same time period the amplitude was there was more or less no changes in the amplitude of the SCL signal.

But then with the time the amplitude of the SCL signal it changed a lot significantly over a period of time then sort of became steady over there, right. So, basically this is representing the general arousal level or the general stress level of an individual rather than the response of the individual to an external event, right.

So, this is very important to understand that when we want to observe the response of an individual to an external event, to a stimuli, to a image to a video, to a music that we are showing we have to look at the SCR component of the signal. But when we want to understand how what is the general level, general arousal level or the general stress level of the individual then maybe we want to look at the tonic component which is the SCL component, right. Not so hard to understand.

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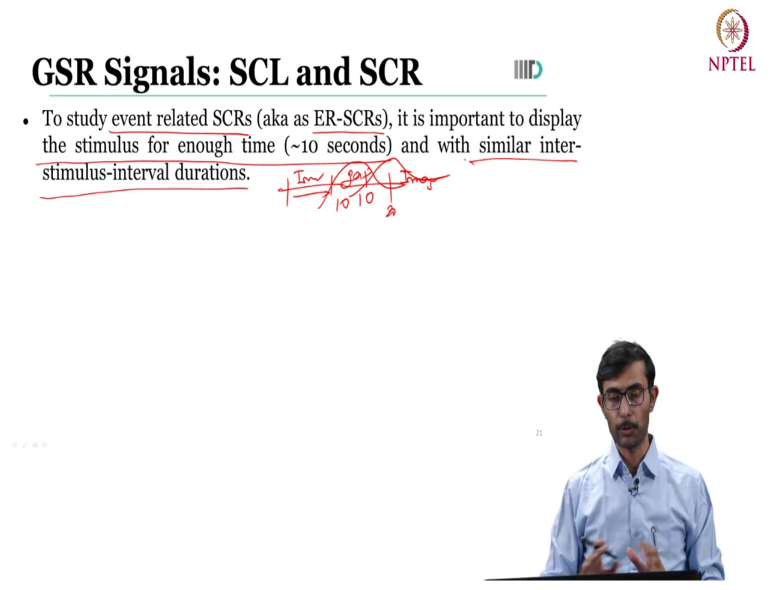

Of course, more importantly we will have to understand that how to differentiate between these two we will come back to that in a minute. So, as I said to study event related SCR's what we want to do these are known. So, SCR's usually they occur as I said when they occur in response to an external event they are known as the event related SCR's, right.

So, basically to understand this event related SCR's or to and to analyze these event related SCRs this is really important for us to display the stimulus for a long enough duration. Because even if it occurs frequently, but what happens that if you are going to show it only for a let us say very very small time 1 second 2 seconds then you already know that the response time of the GSR signal itself is a bit is a slow responsive signal.

So, there is a latency from the stimulus onset to the appearance of the GSR signal. And then of course, it takes certain time to go to the peak and then it takes certain time to come to the baseline. And for the same reason what you want to have? You want to also have a similar inter stimulus interval durations.

What it means, that you may want to present let us say an image for 10 seconds and in order to and then you want to analyze the effects of that image on the GSR signal and then maybe you want to take a gap of 10 seconds before even presenting the another image for 10 seconds again, right.

Why you want to do this? Because of course, if you are not going to maintain proper gap between the presentation of two stimulus two stimuli component then there could be an overlap in the response of the stimuli, right. So, again I will just make your life easier here.

So, for example, this is an this is the let us say first two second you presented one image then you may want to keep a gap of let us say another 10 seconds and then this becomes 20 here and then again you want to present and you may want to present another image. And that is how you analyze. Else, what will happen? That the response of this particular thing is going to overlap with the response of the next image or the next stimulus that you are presenting.

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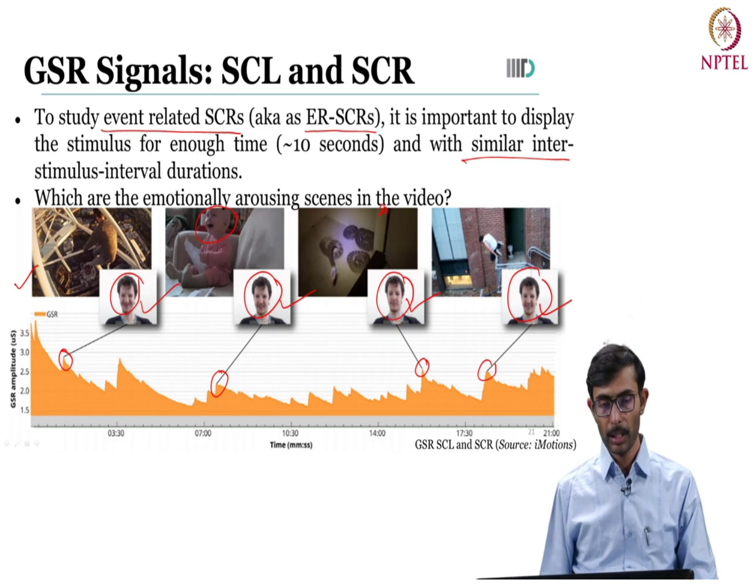

So, you may not want to do that because it is going to give you like multiple responses and an overlapping responses perfect. So, other thing that now and if you look at this how we observe the response of the GSR when let us say watching a particular stimulus then this is a very nice example where what you are looking at that this is the GSR response GSR signal response when an individual let us say who is looking in the image is watching some particular images or is watching some particular arousing scenes in a video.

So, sorry for example, if you look at this particular a scene then what is happening here? That the individual is walking at a very tall height maybe on a skyscraper where there is a glass and the individual is able to see from a very top height. So, basically here it is a very very arousing scene and again you can see the response. Again, similarly there is a baby which is a cute baby. So, again there is arousing response and then you can see again the corresponding facial image, facial expressions or the a response of the individuals in this face.

And accordingly, so for this particular component you can see that how you can see there is a peak GSR peak present for the most arousing parts of the these scenes or of these videos. And that is how you know we timestamp the of course, we have a timestamp for the scenes that are getting presented. And accordingly, we try to put this timestamp or we try to make the signals responses also in sync with the images or the videos that are getting represented.

And then we look at we observe those responses with respect to the arousing scenes and then we try to see you know such as here that ok, when the individual is looking aroused what was the corresponding GSR signal. And if the GSR signal looks out to be ok with the arousing then what exactly was the individual looking at that particular point of time. So, this is how we look at the entire setup and this is how we analyze the emotionally arousing scenes let us say in a video or for example, in any particular stimuli, perfect.

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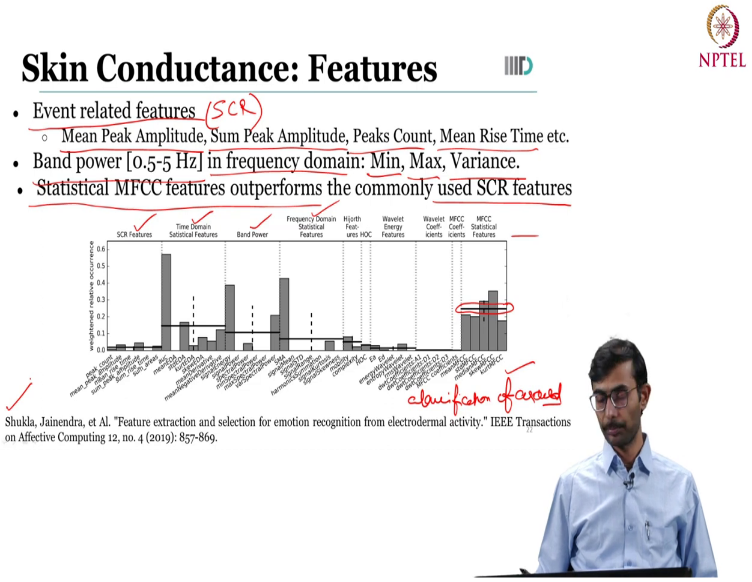

So, having understood that how the GSR signals respond what are the different components of the GSR signal. Now, there are n number of different features of the GSR signals. So, and these features could be you know since we are talking about a time series signal. So, GSR signal essentially is a time series signal, right. So, a time series signal can be analyzed in time domain, it can be analyzed in frequency domain, it can also be analyzed in the time frequency domain.

So, without going too much into the signal processing part there are certain for example, most important features that are related to the skin conductance or the GSR signal is the event related features. So, basically the event related features are the features which are response to an event, to response to an external event. So, you may have rightly guess that these are the events that you are looking into the mostly the SCR, right. So, basically whenever you have an SCR you may want to look at the there are multiple SCRs there can be multiple SCR's.

So, for example, here you can see one SCR, two SCR, here SCR and so on so forth. So, basically there are multiple peaks that may be there. So, you may want to look at the what is the peak mean peak amplitude, what is the average peak amplitude. Similarly, you may want to look at the what was the sum of all the peak amplitudes.

Similarly, you want to count the number of peaks, you want to look at the what is the mean rise time for each of them peaks and so on so forth. So, it takes a bit of signal processing to extract these features, but these are not very hard. And it turns out these are very very popular signals features when we are analyzing the GSR responses.

Similarly, another very popular feature when we are analyzing the GSR signal is in the frequency domain which is very very simply as the band power of the GSR signal. So, basically when we try to analyze the band power of the GSR signal, then what we simply do? We try to identify or understand the band power the spectral band power of the signal in different frequency band. So, for example, we look at the band power from 0.5 hertz, then we look at the what is the band power at 1 hertz, similarly 1.5, 2.5 and so on so forth.

So, basically, we create different bands of the signal GSR signal in the frequency domain and of course, once we have the spectral power, then we try to look at ok, which is the minimum spectral power, which is the maximum spectral power and we can look at the what is the variance in the spectral power.

So, basically these are some statistical features that we obtain on this band powers that we calculate in the frequency domain. Again, so quite simple features to analyze and it turns out that this very very important feature when it comes to the analysis.

In a paper in 2019, our group showed that you know in apart from these features, which are the commonly used, let us say SCR features, what the statistical MFCC features. So, basically MFCC you may have heard the (Refer Time: 22:15) frequency spectral spectrum features. So, basically the MFCC features, these features are very very important feature and at least when we try to analyze the GSR signals. And it turns out that they even outperform the commonly used SCR feature.

So, for example, without going into too much detail on this particular diagram so, basically this diagram is representing the weighted occurrence or let us say the weightage of a particular a feature for a particular classify while doing the classification of the arousal. So, here what we wanted to do, we wanted to do the classification of arousal.

And while doing the classification of the arousal, we analyzed the features in the you know we analyzed its SCR features, we analyzed the time domain features, we analyzed the band power feature, frequency domain features and so on so forth. So, basically these are the different features that we analyzed.

And then if you look at this particular bar here, what it shows that the weightage of the MFCC statistical features were much higher than in comparison to let us say you know all these SCR band power frequency domain features. And that is how we concluded that statistical MFCC features they outperform the commonly used SCR features. And for more details, I will invite you to please look at this particular interesting paper that our group published in this domain in 2019, right, perfect.

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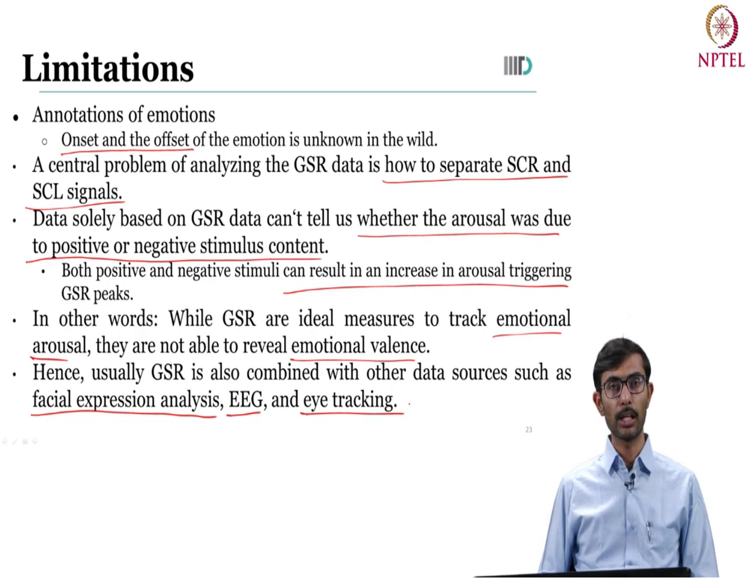

So, these are the of course, some of the features when we try to analyze the GSR signal and it takes a bit of single processing, you need not to worry about that. There are different tools which can do this job for you and at the end of this class; we will try to give you a demo about it.

So, when it turns that you know like there are certain limitations that are associated with the GSR signal as well when we try to analyze the emotions. One very commonly, very common limitation across physiological signals is that how can we label the emotions that are associated with the physiological signal or in this case the GSR signal.

The reason that we found it challenging because when we are analyzing or monitoring the GSR signals or any physiological signal in the wild in real time, then what happens that the onset or the offset of the emotion is not known a precisely, right. So, for example, when we are trying to recall the particular fact in front of an audience.

Of course, we do not know exactly when we started to recall the fact in front of the audience and of course, maybe there is a very less possibility of being able to do the annotation of or marking the timestamp when you started recalling that particular fact because of course, you are in the wild, right.

So, this is this becomes a bit tricky because then the synchronization becomes a problem and then accordingly in the classification and then everything becomes a bit of a problem. Other thing that you may have you know this question may have come to your mind when we were talking about the SCR and the SCL that how to separate the SCR and the SCL signals.

This is a central problem, but then there are lots of tools nowadays which are available online and we will provide you some links also through which you can do the separation of the GSR signal into the SCR and the SCL signals, the SCL signals without much trouble.

So, the these tools which are available online which are available they make you which have been published by the previous researchers, early researchers in the domain they make your life a lot easier. So, you need not to worry about that, perfect. Now, so other problem that is there and a very important problem with the GSR signal that it does of course, it tells that you know like that the individual is aroused, the individual is stressed, but the problem is it does not tell you whether that arousal or that is stress was due to a positive stimuli or due to a negative stimuli.

So, it may happen that you may feel aroused because of a positive experience or you may feel aroused for example, because of a negative experience. And in both the kind of stimuli's what happens that it results in an arousal which is triggering the number of GSR peaks let us say, you may have the same number of peaks when you are aroused in response to a positive stimuli or when you are aroused in response to a negative stimuli.

So, it does not help you differentiate what is the direction of the emotion. It tells you that you there is an arousal, but it does not tell you what is the direction of the arousal, right. So, it is a it is a severe limitation. So, of course, in other words if you recall the emotion theory then of course, it helps you to track the emotional arousal, but it does not tell you anything about the emotional balance.

So, if you recall the VAD and the PAD component. So, we have the information about the arousal, but we do not have the information about the balance at least when we simply use the GSR signal. And it is for the same reason that what we do when we make use of the GSR signals you we usually combine the GSR signals with other data sources such as of course, you as you saw the facial expression analysis, the one that I showed you before, we can even combine it with the other physiological signals such as EEG, electron cephalography signals.

And of course, we want to look at the eye tracking to observe the gaze tracking of the individual gaze tracking data of the individual. So, this is how you know in general in short this is how we use the GSR signal to understand the arousal and then when whenever required we combine the GSR signal with the other data sources in order to obtain more information.

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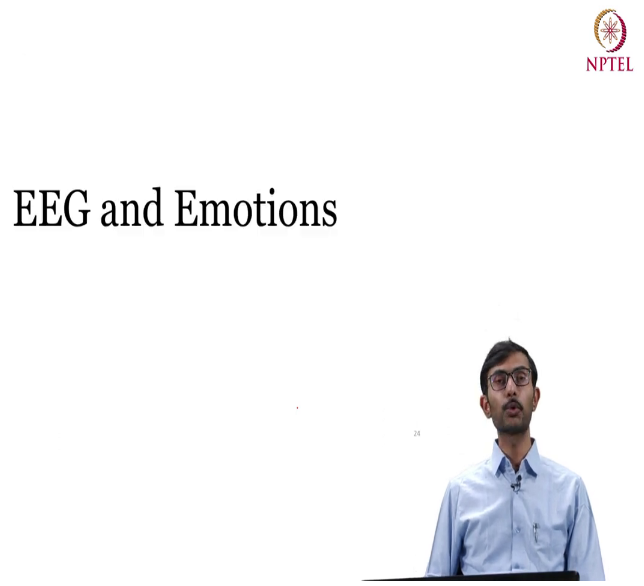

Now, let us try to look at how the emotions are represented in the EEG signal.